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Original Article

Characteristics of sleep apnea syndrome in tetraplegic patients

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Objective: To include a larger number of tetraplegics than in previous studies, in order to more reliably characterize the pathogenesis and predisposing factors of sleep apnea in tetraplegia.

Methods: Sleep breathing data and oxymetric values were investigated in 50 randomly selected tetraplegic patients and discussed in context with age, gender, BMI, neck circumference, type and height of lesion, time after injury, spirometric values and medication. A non-validated short questionnaire on daytime complaints was added.

Results: Thirty-one patients out of 50 had an RDI $\geqslant 15$, defined as sleep disordered breathing (SDB); 24 of them combined with an apnea index of 5 or more, these cases were diagnosed as sleep apnea syndrome (SAS). SAS was apparent in 55% and 20% of the studied men and women, respectively. Regression analyses showed no significant correlation between RDI and lesion level, ASIA impairment scale or spirometric values. In contrast, a significant correlation between RDI and age, BMI, neck circumference and time after injury could be shown. Kruskal-Wallis test for dichotomous non-parametric factors, such as gender, cardiac medication and daytime complaints, showed significant differences with regard to RDI. In contrast to able-bodied people with SAS, daytime complaints were only present in tetraplegic patients with severe pathology (RDI > 40).

Conclusion: Incidence of SAS is high in tetraplegia, particularly in older male patients with large neck circumference, long standing spinal cord injury and under cardiac medication. As tetraplegics with RDI between 15 and 40 reported no daytime complaints and often have normal BMI, these tetraplegics are not clinically suspicious for SAS. The increased use of cardiac medication in tetraplegics with SAS may implicate a link between SAS and cardiovascular morbidity, one of the leading causes of death in tetraplegia.

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Introduction

The prevalence of sleep apnea syndrome (SAS) in tetraplegic patients is known to be more than twice as high as in the general population.[1–3] In 1968 Adey and colleagues[4] investigated sleep disturbances with electroencephalogram (EEG) in 18 spinal cord injured patients and described a fragmented sleep architecture with a deficit of deep sleep and REM sleep in tetraplegic patients. The paraplegic patients presented also sleep deficits, but a stable relation between the different sleep stages and REM sleep. Without further parameters (eg oxymetry) they concluded that the absence of complex motor activity is the main reason of the distortion of sleep pattern. Although in 1982 Braun and colleagues[5] screened 11 tetraplegic patients with nocturnal oxymetry and found pathological results in two patients, the importance of SAS in tetraplegic patients has been recognized only in recent years.[2,3]

Different predisposing factors that contribute to this increased incidence were discussed in several studies: paralyzed intercostal and abdominal muscles, impaired activation of diaphragm (in lesions above C5), increased upper airway obstruction and supine sleep posture.[2,3,6–10] Nevertheless, the pathophysiology of SAS in tetraplegia is not yet fully understood.

In non-disabled patients with SAS an increased risk for adverse health effects as hypertension and vascular mortality is described.[1,11,12]

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It is the aim of this study to elucidate the characteristics of sleep apnea syndrome (SAS) in tetraplegia and look for predictors as well as symptoms of SAS in a large cohort of patients. Factors that might contribute to different degrees of sleep disordered breathing (SDB) in tetraplegia are discussed in light of our findings and pathogenetic reflections are added.

Methods

Subjects
We randomly selected 50 post-traumatic tetraplegic patients with stable cardio-pulmonary function. Spinal cord lesion levels were between C3 and C8. The motor- and sensory levels and the impairment scale were determined using the American Spinal Injury Association (ASIA) standards.[13] Ten subjects were females and 40 were males. The mean age of the patients was 48.6 years ($\pm$14.0), range 20–81 years. They were a mean of 11.4 years postinjury (range from 0.5 to 37 years).

Body mass index (BMI) was calculated (body weight/height squared (kg/m^2)) for all subjects studied and neck circumference recorded in sitting position in a subgroup of 16 patients. Motor and sensory examinations were performed and all patients were classified using the ASIA impairment scale A–D. An informed consent for the polygraphic recordings was obtained from each patient.

Polygraphic sleep studies
In all patients sleep recordings were performed in hospital with measurement of airflow by oronasal thermistor, oxygen saturation by pulse oximetry (finger-probe SaO_2), and respiratory effort by abdominal wall and thoracic wall motion recording. The data were recorded with a multichannel digital polygraphic system, model POLY-MESAM (MAP, Martinsried, Germany). Measurements with this device are validly compared with hospital-based polysomnography.[14]

Respiratory analysis
The number, duration and type of apnea and hypopnea were calculated automatically first and then visually checked for missed apneas/hypopneas and artefacts, which were rejected. Hypopnea was defined as a reduction in airflow-amplitude of 50%–90% from baseline, lasting 10 s or more. Baseline was determined as a function of gliding maxima-average over 10 breaths. Apneas were defined as a reduction in airflow-amplitude of 90%–100% of baseline, lasting 10 s or more. They were further subdivided in: (1) obstructive apnea, defined as respiratory effort only; (2) central apnea, defined as lack of respiratory effort; (3) mixed apnea, defined as initial lack of followed by a respiratory effort. The number of apneas per h of time in bed was defined as apnea index (AI); the sum of apneas and hypopneas per h as respiratory disturbance index (RDI). Patients with an RDI of 15 or more and an AI of five or more were defined as SAS patients. As daytime sleepiness did not significantly differ between tetraplegic patients with SAS and without SAS,[2,8,15] we restricted the definition of sleep apnea syndrome in tetraplegics only to the respiratory data.

The percentage of the oxygen-saturation in the peripheral blood was determined with the pulse oximeter. Pathological events of desaturation are defined as a 4% decline of saturation (oxygen of the hemaglobin) below the baseline. Baseline saturation was determined as a gliding average of the saturation integral over the last 30 s of registration.

The minimum oxygen saturation was defined as the lowest pulse oximeter reading over the entire recording period. Desaturation index (DI) was defined as the mean number of pathological events of desaturation per h.

Pulmonary function studies
Spirometric data (consisting of forced vital capacity (FVC) and forced exspiratory volume in 1 s FEV1.0) were measured in seated position with a portable spirometer (model CS 100, Schiller Recomed AG, Dietikon, Switzerland) before the subjects were equipped for the polygraphic studies.

Reports of daytime complaints
Most of the investigated tetraplegic patients denied the symptom of sleepiness, even though some of them were obviously sleepy.

Although the Epworth sleepiness scale (ESS) is a standardized simple and self-administrated method for measuring the general level of daytime sleepiness, and ESS scores were related to the severity of sleep apnea syndrome,[16] it was not applied in our study. Most of our patients were not able to write the answers themselves and some situations described in ESS were not applicable for them (eg car driving, outside visits). Consequently, we chose a short non-validated interview to assess sleepiness, where the answers were restricted to 'yes' and 'no'. This questionnaire assessed daytime sleepiness and tiredness, before and after injury.

Drug report
We recorded the use of cardiac medication (anti-hypertensiva and antiarrhythmica) as well as antispastic- and sedative drugs as dichotomous parameters.

Treatment studies
Sixteen out of 31 patients with pathological RDI decided for therapy and received a second sleep study during which a personally adapted nasal mask was applicated. Detailed results of this treatment study will be presented elsewhere. In the present study we report patients compliance and discuss factors that contribute to it.

Data analysis
Linear correlations were performed between RDI and age, BMI, neck circumference, height of lesion, ASIA impairment scale, time after injury and spirometric values. Statistical significance was set at a probability of 0.05. Non-parametric tests (Kruskal-Wallis) were used to examine the difference between the dichotomous factors such as gender (male/female), ASIA impairment scale (motor complete: ASIA A, B/ motor incomplete: C, D), cardiac- and antispastic medication (present/absent), and reported daytime complaints (present/absent).

Results

Respiratory and oxymetric data

Incidence of sleep apnea The polygraphic data showed that 31 out of the 50 tetraplegic patients had an RDI of 15 or more (mean 30.5), defined as sleep disordered breathing (SDB). Twenty-four out of these patients met the criteria of RDI of 15 or more and AI of five or more, diagnosed as sleep apnea syndrome (SAS). The incidence of SAS was therefore 48%. Study population demographic- and pulmonary data are listed in Table 1 and sleep breathing data in Table 2.

Characteristics of apneas, desaturation index and minimum SaO_2 The RDI correlated significantly with the desaturation index (DI) and was significantly inversely correlated with the minimum SaO_2 (see Table 3). There was no significant relation found between pulmonary function data and DI or minimum SaO_2.

Table 1 Demographic data

	Mean values ± SD (n = *50*)
Age	48.6 ± 14.0 years
Gender (numbers)	
females	10
males	40
BMI	24.6 ± 5.2 (kg/m^2)
Neck size ($n=16$)	426 ± 63 mm
Height of lesion	
mid cervical C3-C5	23
deep cervical C6-C8	27
Motoric impairment	
complete	40
incomplete	10
Time after injury	11.4 ± 9.7 years
FEV1 (l)	1.9 ± 0.6
FEV1 (% of predicted)	51.8 ± 11.3
FVC (l)	2.3 ± 0.6
FVC (% of predicted)	56.7 ± 16.2
FEV1/FVC (% of predicted)	76.7 ± 11.2
daytime complaints	
yes	12 (92% with SDB)
no	38 (53% with SDB)

Table 2 Sleep breathing data

Measured variables	*Mean values ± SD* (n = *50*)
RDI (events/h)	30.5 ± 24.7
Apnea Index (AI) (events/h)	12 ± 15.2
AI obstructive (events/h)	7.2 ± 11.1
AI mixed (events/h)	2.2 ± 5.3
AI central (events/h)	2.0 ± 3.7
Hypopnea Index (events/h)	18.5 ± 16.2
Desaturation Index (dl) (events/h)	26.4 ± 23.9
Minimum SaO_2 (%)	72.6 ± 14.5

Out of the tetraplegic patients with SAS ($n=24$) three groups could be differentiated: (1) patients with predominantly central apneas ($n=2$); (2) patients with predominantly mixed or combined mixed and central apneas ($n=6$); and (3) patients with predominantly obstructive apneas ($n=16$). Apnea Index for central-, mixed- and obstructive apneas as well as hypopnea Index (events/h) are also listed in Table 2.

RDI in correlation to subject data and paralysis-characteristics
All patients below 40 years ($n=11$) had a normal RDI (<10). RDI was significantly correlated with age (Table 3).

The total 50 subjects included 40 men and 10 women. SAS was present in 55% of the males and 20% of the females. The Kruskal-Wallis test showed a significant difference for gender with regard to RDI (Table 4).

The mean BMI was 24.6 (±5.2). A significant correlation was found between RDI and BMI for the whole group of 50 patients; but not for the subgroup of patients with SAS ($n=24$). BMI was significantly inversely correlated with the minimum SaO_2 ($r=-0.7$, $P<0.0001$).

Neck circumference was measured only in a subgroup of 16 tetraplegic patients, eight with and eight without SAS. Mean neck circumference was 426 mm (±6 mm). There was a significant correlation found between neck circumference and RDI as well as a high inverse correlation between neck circumference and minimum SaO_2 ($r=-0.8$, $P=0.0002$), Figure 1. Patients with a mid cervical lesion (C3–C5, $n=9$) had a mean neck circumference of 449 mm (±71 mm), whereas mean neck circumference of patients with a deep cervical lesion (C6–C8, $n=7$) was 396 mm (±37 mm). However, neck circumference was not significantly correlated to lesion level.

Out of 50 patients 23 subjects had a mid-cervical lesion (lesion level C3–C5). The only patient with C3 level had a motoric incomplete lesion. Twenty-seven subjects had a deep cervical lesion (C6–C8). As seen in Figure 2 no significant relation between RDI and height of lesion was found. Forty patients had a complete motory lesion (ASIA A or B), and 10 had an incomplete motor lesion (ASIA C or D). No significant correlation between RDI and ASIA scale was found.

Table 3 Inner correlation between RDI and listed variables plus standard deviations of different RDI-classes

Measured variables	*RDI < 15* (n = *19*)	*RDI: 15–40* (n = *12*)	*RDI > 40* (n = *19*)	P-*value*
Desaturation index (events/h)	5.5 ± 4.3	26.8 ± 8.1	57.7 ± 12.1	0.0001
Minimum SaO_2 (%)	83.9 ± 9.5	67.6 ± 11.7	64.3 ± 13.3	0.0001
Mean age (years)	38.8 ± 13.7	57.3 ± 12.4	52.9 ± 8.9	0.005
BMI (kg/m^2)	21.6 ± 4.8	25.3 ± 3.4	27 ± 5.2	0.001
Neck size (mm)	375 ± 31 ($n = 7$)	470 ± 82 ($n = 3$)	463 ± 40 ($n = 6$)	0.02
Time after injury (years)	9.1 ± 7.6	9.8 ± 8.8	14.7 ± 11.4	0.03
FEV1/FVC (%)	76.6 ± 10.5	72.4 ± 10.2	78.8 ± 12.2	ns

Data are expressed as mean ± SD; SDB = sleep disordered breathing; ns = not significant

Table 4 Ratio of non-parametric variables of tetraplegic patients with no, moderate and severe SDB

Dichotomous groups	*RDI < 15*	*RDI 15–40*	*RDI > 40*	P-*value*
Males : Females (% females)	12:7 (36.8)	10:2 (16.7)	18:1 (5.3)	0.006
Motor impairment complete : incomplete	15:4	10:2	15:4	ns
Cardiac medication yes : no (% patients with medication)	0:19 (0)	2:10 (16.7)	5:14 (26.3)	0.04
Antispastic medication yes : no (% patients with medication)	9:10 (47.4)	10:2 (83.3)	15:4 (79)	ns
Benzodiazepine intake yes : no (% patients with medication)	3:16 (15.8)	4:8 (33.3)	4:15 (21)	ns
Daytime complaints yes : no (% with complaints)	1:18 (5.3)	0:12 (0)	11:8 (57.9)	< 0.0001

P-values are given for the Kruskal-Wallis test of the dichotomous variables shown in the first column (ns = not significant)

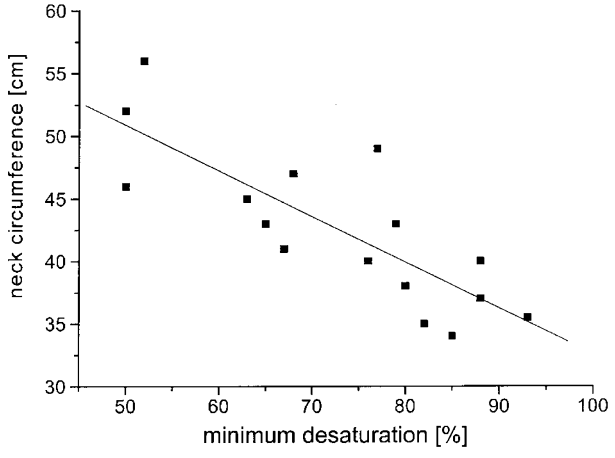

Figure 1 Inverse linear correlation ($r = -0.81$, $P = 0.0002$) between neck circumference and minimum desaturation of a subgroup of the subjects ($n = 16$)

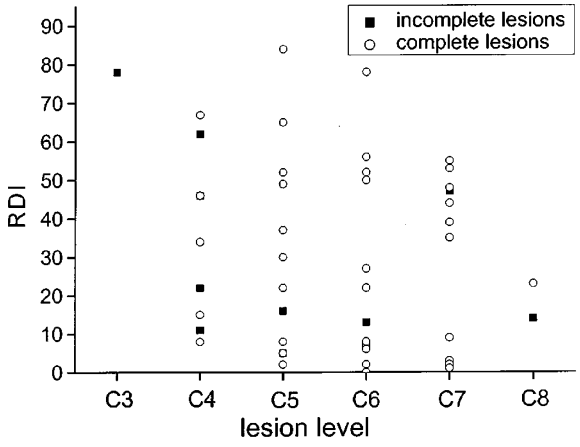

Figure 2 Distribution of RDI according to lesion level. Different symbols are used for motory complete (ASIA **A, B**) and incomplete (ASIA **C, D**) lesions

A significant correlation was found between RDI and the time postinjury (Table 3).

RDI and pulmonary function data

Spirometric data mean ± SD are shown in Table 1. RDI did not significantly correlate with lung function data.

RDI and daytime complaints

The Kruskal-Wallis test showed a significant difference in RDI between patients with and without daytime complaints ($P < 0.0001$). Nevertheless, only nine out of 24 patients (37.5%) with SAS complained about daytime tiredness and sleepiness (Figure 3). These subjects with daytime complaints had a severe sleep pathology with an RDI over 40. One patient with

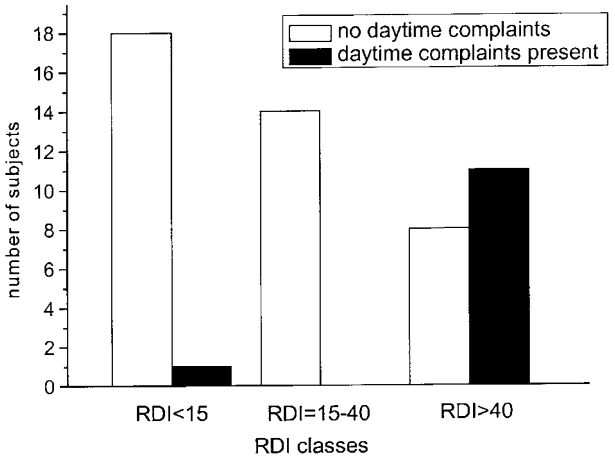

Figure 3 Presence of daytime complaints according to RDI

normal nightly breathing pattern also had daytime complaints.

Treatment outcomes
Sixteen out of 31 patients with pathological RDI accepted a trial with a long term positive pressure therapy. Five of these 16 patients discontinued the therapy after a few weeks, four did so because of mask discomfort and one because of anxiety. Ten out of 11 patients (91%), who continued therapy had daytime complaints before starting therapy and showed improvement of symptoms during therapy. Of the 15 patients with pathological RDI that did not accept therapy, only one reported daytime complaints.

Medication
Thirty-four out of 50 patients had taken antispastic medication; 30 patients took baclofen and seven of them had intrathecal application. Eleven patients took benzodiazepines, nine in combination with antispastic medication. The Kruskal-Wallis test showed no significant difference with regard to RDI for neither of benzodiazepine intake nor for antispastic medication.

Different degrees of SDB and demographic data
As episodes of oxygen desaturation and arousal induction (sleep fragmentation) may be caused by hypopneas as well as apneas, we used three different groups of RDI (sum of apneas and hypopneas) to distinguish severity of SDB: group (A) tetraplegic patients without sleep disordered breathing (RDI <15), group (B) patients with moderate SDB (RDI 15–40) and group (C) patients with severe SDB (RDI >40).

Table 3 shows the linear correlation between RDI and the listened variables plus the means and standard deviations of the three different RDI-classes. Table 4 shows the ratio between the dichotomous variables such as gender, impairment scale, medication use, and presence of daytime complaints for the three RDI classes.

Compared to subjects with a normal RDI, patients with moderate and severe SDB were mostly male, older, slightly fatter, had an increased neck circumference and an increased intake of cardiac medication. Comparison between tetraplegic patients with (1) moderate SDB and (2) severe SDB showed an increased mean postinjury time, while the other variables were similar in all groups.

Discussion

The main findings of the present study are that the incidence of sleep apnea is high in tetraplegia and significantly positively correlated with age, BMI, neck circumference and time after injury. In contrast to able-bodied populations with SAS, most of the concerned tetraplegic patients have low clinical suspicion for SAS: they are not obese and daytime complaints are only present in severe cases (RDI >40). Furthermore, the use of cardiac medication is significantly more frequent in tetraplegics with SAS than in tetraplegics with normal nightly breathing. Therapy compliance was with about 30% low and related to the presence and improvement of daytime complaints.

With 48%, the prevalence of SAS in the studied patient group was very high. The mean age of the tetraplegic patients was almost 50 years and therefore comparable with the results of Short and colleagues,[9] who observed a 45% prevalence of SDB in 22 tetraplegic patients over 40 years. Similarily, in the study by Burns[15] the median age of the SCI patients (12 tetraplegics, eight paraplegics) was 50 years and the prevalence of SAS was 40%. In the study of Cahan, six out of 16 tetraplegics (37.5%) with a mean age of nearly 49 years had SaO_2 profiles outside of the normative range.[3] Although different methodology of recording – varying from only oxymetry to full polysomnography – and nonuniform definitions of SDB and SAS make a comparison with other studies difficult, a high prevalence of SDB of between 15% to 38% in 'non-selected' younger SCI patients is found in most studies.[2,3,8] In the acute state until 6 months after injury, the prevalence seems to be higher (with 30% to 83%) than in the chronic state.[17,18]

Influence of different variables on SAS in tetraplegics
Our study shows a significant correlation between RDI and age, as described in various studies with non-paralysed patients with SAS,[1,19] but not in studies with tetraplegics.[2,7,8,20] This difference may be related to the greater number of studied tetraplegics than in previous studies. A further reason may be a selection bias of some studies that overrepresents young subjects more prone to accidents leading to SCI.

Further predictors for SAS in non-paralysed able-bodied patients are male gender, high BMI as well as presence of daytime sleepiness. These parameters are controversial in studies with SCI subjects.

In most studies of SCI subjects, none or only few females were included.[2,7,9,20] In our study 10 females were included and two of them met the criteria of SAS (20%); the incidence of SAS amongst men was with 55% more than twice as likely as women. These results of gender distribution agree with a population-based study of Young and colleagues,[1] whereas the general incidence of SAS in tetraplegics in comparison to non-disabled population was distinctly higher. Young and his group investigated 602 randomly selected subjects between 30 and 60 years and found an RDI $\geqslant 5$ in 9% of the investigated women. They showed that men were 2.0–3.7 times more likely than women to have SDB, defined as RDI $\geqslant 5$. In the study of Klefbeck five out of 33 SCI patients were females and none of them had a pathological RDI.[8] However, in his study only three subjects out of the whole group had SAS, a fact that must be considered when interpreting his results.

BMI is a second well known risk factor for SAS in non-disabled patients. In agreement with the results of another large study of Burns,[20] we found a significant correlation between RDI and the controversal factor of BMI. Mean BMI of our studied patients was in the normal range, and most tetraplegic patients with SDB were not morbidly obese (RDI <30). If we compare the mean BMI values in the three different RDI classes, we find a trend for increasing BMI with more severe SDB. In the non-paralysed population, obesity is strongly associated with SAS.[21,22] This is true also for tetraplegics (in our study seven out of eight patients with BMI over 30 had SDB), however, tetraplegics with moderate SDB had a mean BMI of 25.3. This subgroup of normal to marginally obese tetraplegics is therefore clinically non-suspicious for SDB. These findings indicate, that already a normal BMI may be considered as a risk factor for SAS in tetraplegia. This notion underlines the recommendation of Pfeiffer[23] for an ideal body weight of 7–9 kg less for tetraplegics, due to loss of weight that tetraplegics experience after their injury.[24]

Because of the difficulty with BMI discussed above, enlarged neck circumference seems to be a better predictor of SAS in tetraplegia than BMI. We found a high correlation between neck circumference and RDI as well as minimum nightly desaturation. An explanation of this finding might be a redistribution of body fat in SCI by an increase in neck circumference (without increasing BMI) provoking nocturnal obstructive apneas, as discussed by the group of McEvoy.[2] This fat redistribution may be related to a pathological insulin sensitivity due to altered sympathetic function in high spinal cord injury.[25] An other explanation for the increased neck circumference is the result of hypertrophy of the neurologically spared accessory muscles of respiration in the neck.[26] In our subjects, patients with mid cervical lesions (C3–C5) had a non-significant trend to higher mean neck circumference than in patients with deep cervical lesions (C6–C8).

In agreement to other studies we found no significant relations between RDI and pulmonary function data.[2,8,27] Also in accordance with other studies neither a significant relation between RDI and injury level nor ASIA impairment scale could be found.[2,3,17] In contrast to the study of Burns[20] we did find a significant relation between RDI and time after injury. In the study of Burns[20] the mean postinjury time and standard deviation of the investigated 42 tetraplegic patients was with 16.4 ± 12.6 years higher in comparison to our study group. This may imply that the risk to develop a sleep apnea syndrome is predominantly in the first decade after injury.

Whereas different studies describe no relation between RDI and self reported sleepiness,[2,8,15] we found a highly significant correlation between RDI and daytime complaints. The following facts could explain this difference to other studies: (1) In our patients, daytime complaints were restricted to patients with severe SDB (RDI <40) and this patient group was overrepresented in our study group in comparison to other studies; (2) In other studies a different measuring methodology to obtain sleepiness was taken (the Epworth Sleepiness Scale [ESS]) and most patients in their study had increased ESS scores independent of their breathing pattern.

The remaining relatively high number of studied tetraplegic patients with SAS but without daytime complaints may be attributed to a decreased arousability during sleep, due to the paralysis and to decreased afferent imput from peripheral mechanoreceptor stimulation. It is assumed that cognitive disturbances in tetraplegic patients are related to nocturnal oxygen desaturations, but not to RDI.[28,29] Possibly cognitive disturbances might be a more reliable predictor of moderate SAS in tetraplegia than daytime complaints. Tetraplegic patients with daytime tiredness and sleepiness but normal RDI are possibly suffering from other sleep disturbances such as periodic limb movements in sleep (PLMS),[30–32] spasticity, pain or insomnia.[33] Arousals not induced by SDB might be the cause of disturbed sleep architecture, loss of deep sleep and consecutive daytime complaints.[2,3]

Risk factors, complications and therapeutic aspects of sleep apnea in tetraplegia

An increased incidence of SAS and SDB in tetraplegic patients may be the result of paralysed intercostal and abdominal muscles, impaired activation of diaphragm, elevated upper airway resistance, sleep posture, antispastic medication, weakened laryngeal muscles due to previous intubation, as well as significant changes in compensatory reflex responses to ventilatory loading, due to disrupted feedback afferents from rib cage

receptors.[34] In several studies airway hyper-responsiveness to pharmacological agents such as histamin or methacholine, but also distilled water, is described in tetraplegia.[35] This airway hyper-reactivity in tetraplegic patients is discussed in context with autonomic nervous system inbalance, altered mechanical properties of the lungs, and an inadaquate stretch of the airway with deep breathing.[36] It is possible that airway hyper-reactivity may be pronounced during the night thus influencing the degree of the obstructive sleep apneas.

Although not significant, a trend of increasing use of antispastic and sedative medication between the group with normal RDI and the two following groups with pathological RDIs was seen.

Different studies suggest a link between sleep apnea and cardiovascular morbidity and mortality in non-paralysed patients.[12,37–39] According to the results of the study of Burns,[20] we found an increased use of cardiac medication in tetraplegic patients with SDB. The fact, that sleep apnea has a high frequency in tetraplegic patients and cardiac disease (ischemic and nonischemic) is one of the leading causes of death in tetraplegia,[40,41] could implicate a relation between both these comorbidities.

Not many studies have been published on therapy of SAS in SCI. Burns describes a low acceptance of CPAP therapy (25%) in eight tetraplegic patients with SAS, contributing to impaired hand function (difficulty with mask positioning).[15] In our study, the start and the acceptance of BiPAP therapy was related to the presence of daytime complaints and the improvement during therapy. After therapy recommendation only 52% of the patients were willing to start a long-term positive airway pressure therapy and 69% of them accepted to continue.

Underlying pathogenetic mechanism of SAS in tetraplegics

Although most tetraplegic patients with SAS had obstructive sleep apneas, in aproximately one third of the tetraplegics with SAS we found high amounts of central and mixed apneas. These results suggest an involvement of additional central factors in the pathogenesis of SAS in tetraplegia, which will further be discussed.

The occurrence of central and mixed sleep apneas in tetraplegic patients may be increasingly activated by secondary symptoms of tetraplegia as follows:

(1) Low functional residual capacity contributes to periodic breathing (several deep breaths alternate with breath cessation during sleep) and central apneic events.[42] In our patients the mean FVC was 2.3 l, ie about 50% – 60% of predicted FVC for an age-matched able-bodied group.
(2) A dysfunction of central CO_2 chemoreceptor sensitivity possibly contributes to an instability in the feedback control of respiration and leads to central apneas in patients with tetraplegia. A lower response to CO_2, as described in post-polio patients, could provoke central apnea.[43] Nocturnal hypercapnia in chronic tetraplegic patients often occurs probably due to a decreased central chemoreceptor sensitivity to hypoxia as well as to CO_2.[27]
(3) In traumatic lesions, followed by edema or posttraumatic processes, such as syrinx formation, an involvement of the ascending reticular fibers of the higher cervical spinal cord is likely and may influence the brainstem respiratory centers. Surgical cervical cordotomy, especially the lesion of the ventrolateral tract for pain treatment, are known to result in severe hypoventilation and repetitive central apneas during sleep, due to the same pathophysiological changes as those observed in chronic tetraplegic patients.[44–46] A high prevalence of central and obstructive apneas is reported also in patients with syringomyelia and syringobulbia, even in the absence of clearcut MRI evidence of medullary involvement.[47] A relation between posttraumatic syringomyelia and central SAS in paralyzed patients has not yet been reported to our knowledge.
(4) Repeated arousals can provoke periodic breathing (combined with central apnea) and lengthening of the phase between wakefulness and sleep thus leads to instability of the metabolically based respiration control mechanisms. It is possible that a ventilation independent arousal disturbance in tetraplegic patients such as spasticity, PLMS, or pain could sustain the repeated arousals, periodic breathing and central apnea syndrome.
(5) In a study of Issa and Sullivan[48] it was shown that the appearance of central sleep apneas could be dependent of posture: in these patients pure central apneas were registrated only in supine position, whereas in the lateral posture mixed apneas appeared. Sleep position in tetraplegics is mostly supine and may influence the characteristics of the apneas.

In conclusion, the high incidence of SDB in tetraplegic patients without daytime complaints but prominent events of oxygen desaturation during the night, emphasizes the importance of performing systematic sleep evaluations and follow-up examinations in this patient group.

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